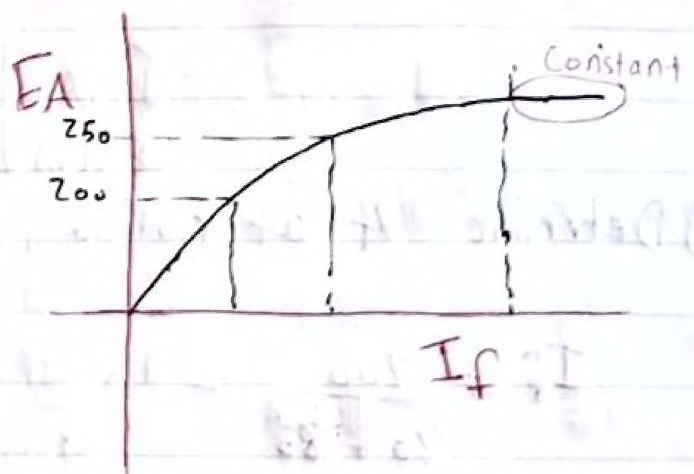
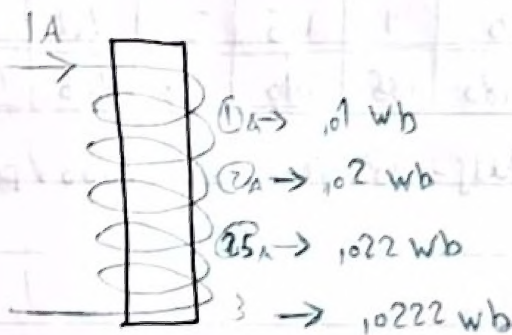


$$E_A = K \phi \omega$$



Ex:  $E_{A1} = 100 \text{ V}$  ,  $I_f = 1 \text{ A}$  ,  $n = 1000 \text{ rpm}$   
 $E_{A2} = ??$  ,  $I_f = 1 \text{ A}$  ,  $n = 1500 \text{ rpm}$

افهم ارجو /  $E_{A1} = K \phi \times n_1 \times \frac{2\pi}{60} = 100$

$E_{A2} = K \phi \times n_2 \times \frac{2\pi}{60} = ??$

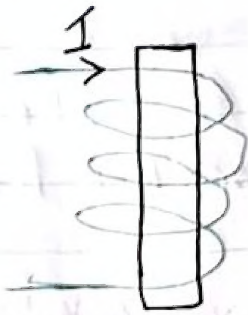
$$\frac{100}{E_{A2}} = \frac{n_1}{n_2} \Rightarrow E_{A2} = \frac{100 \times 1500}{1000} = 150 \text{ V}$$

$E_A$  ,  $R_{adj}$  ,  $n$  يكون متغيرين  
 معاً وينطق الثالث

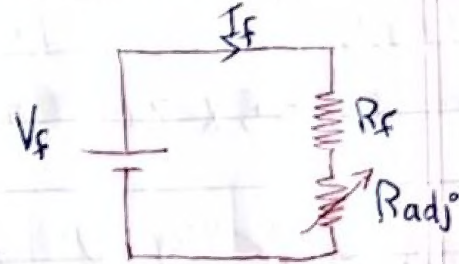


Shunt  $\xrightarrow{\text{always}}$  Parallel

\* flux { permanent magnet  $\rightarrow$  uncontrolled  
elector magnet  $\rightarrow$  controlled



\* field circuit %



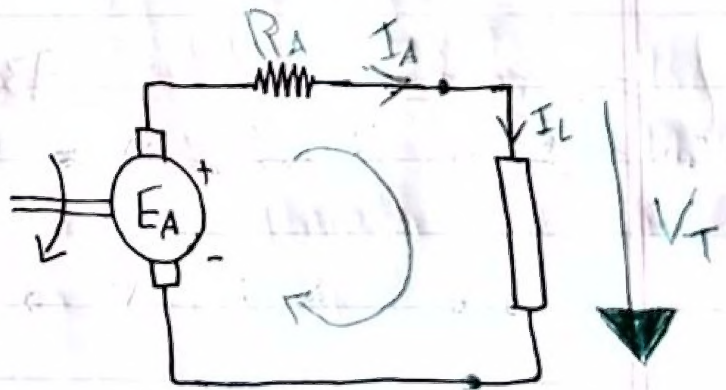
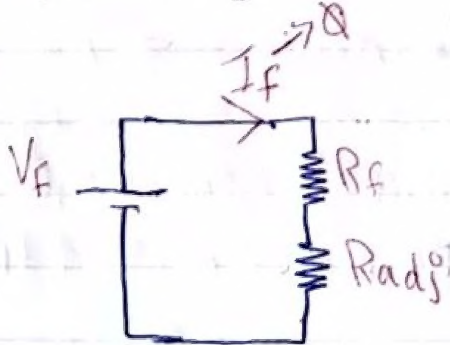
$$\Phi = \frac{\text{MMF}}{R} = \frac{NI}{R}$$

$$I_f = \frac{V_f}{R_f + R_{adj}}$$

(يتم ضبطه)

\* DC - generators types

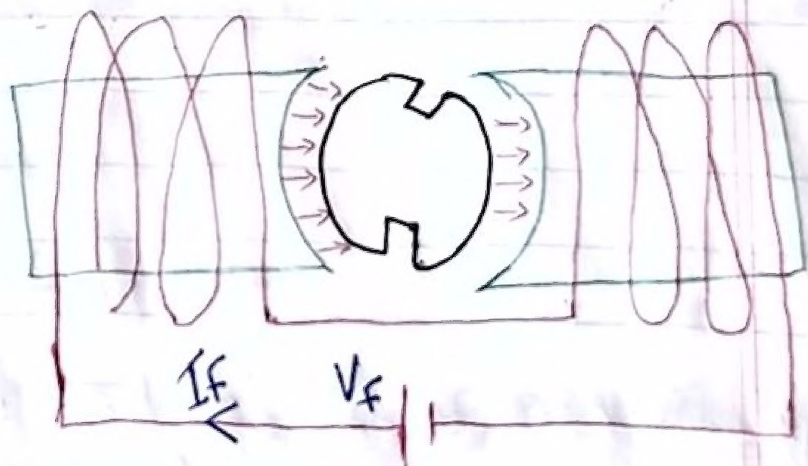
1) separately excited



$$I_f = \frac{V_f}{R_f + R_{adj}}$$

$$E_A = V_T + I_A R_A$$

$$I_L = I_A$$





4) Determine applied torque (Input) for Case (2)  
if friction losses = 100 watt

$$P_{\text{input}} = P_{\text{developed}} + P_{\text{friction}}$$

$$= 155 \times 20 + 100 = 3200 \text{ Watt}$$

$$P_{\text{input}} = k \omega = \frac{640 \times 4}{2\pi \times 4} \times 102 \times \omega = 155$$

$$\omega = 76 \text{ rad/s}$$

$$T_{\text{inp}} = \frac{3200}{76} = 42.1 \text{ Nm}$$

$$\eta = \frac{P_{\text{out}}}{P_{\text{inp}}} = \frac{150 \times 20}{3200} = 93.7\%$$





$$T_{app} = \frac{P_{friction\ losses} + P_{developed}}{\omega}$$

\* Sep excited DC generator  $\eta = 80\%$ ,  $P_{out} = 6kW$   
 $V_f = 200V$ ,  $I_f = 10A$ ,  $n = 1000\text{ rpm}$

Determine applied torque

$$0.8 = \frac{10000}{T \times 1000 \times \frac{2\pi}{60} + 200 \times 10} \Rightarrow T = 100\text{ N.m}$$

\* Power flow diagram

$$P_{deve} = E_A \times I_A$$

$$V_f \times I_f$$

$$+ T_{app} \times \omega$$

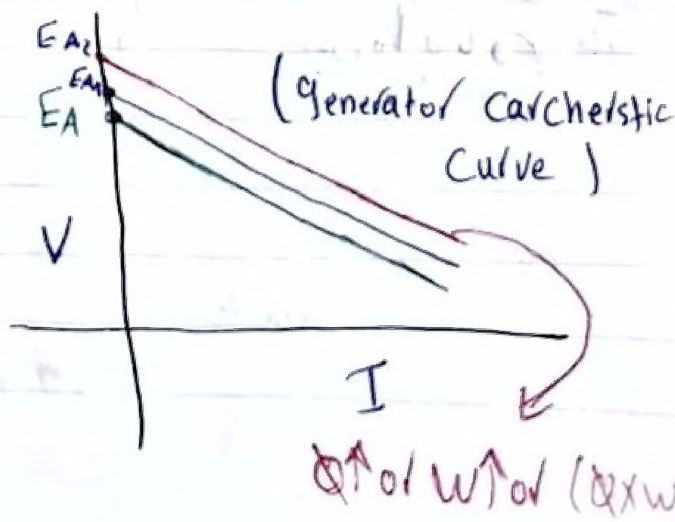
$P_{out}$   
(elect)

non electrical  
losses (friction)

elect losses  
(elect)

$P_{out}$  (electrical)  $V \times I$

$$V_T = E_A - I_A R_A$$





2) Determine  $R_{adj}$  required for the generator to supply out put of 20 KW,  $V_T = 500$  V, Speed = 1000 rpm.

$$I_L = \frac{20000}{500} = 40 \text{ A}$$

$$E_A = 500 + 40 \times 0.12 = 504.8 \text{ V}$$

504.8  $\rightarrow$  1000 rpm كل ما زادت السرعة

$E_A \rightarrow$  800 rpm ينزى

4.8

390

$I_f$

403.8

6.4

460

$$\frac{4.8 - I_f}{4.8 - 6.4} = \frac{390 - 403.8}{390 - 460}$$

$$I_f = 5.11 \text{ A}$$

$$I_f = \frac{V_f}{R_f + R_{adj}} \Rightarrow 5.11 = \frac{200}{25 + R_{adj}} \Rightarrow R_{adj} = 14.14 \Omega$$

$$P_{inp}(\text{total}) = P_{inp}(\text{mech}) + P_{inp}(\text{elect})$$

$$\eta = \frac{P_{out}}{P_{inp}(\text{total})}$$

$$P_{inp}(\text{mech}) = P_{\text{friction losses}} + P_{\text{developed}}$$



## \* DC - sep excited generator

EX: DC - sep excited generator,  $V_f = 200 \text{ V}$

Armature Resistance  $R_A = 0.12 \Omega$ , field Resistance  $= 25 \Omega$

If	1.6	3.2	4.8	6.4	8.1	9.6	11.2	11.8	A
E <sub>A</sub>	148	285	390	460	520	560	590	605	V

1) If the prime mover speed  $= 1200 \text{ rpm}$ ,  $R_{adj} = 6 \Omega$   
 $R_{load} = 10 \Omega$ , determine terminal voltage ( $V_t$ ) and output power

$$I_f = \frac{200}{25 + 6} = 6.45 \text{ A}$$

الجدول  
نبروت  
تقريباً 6.4

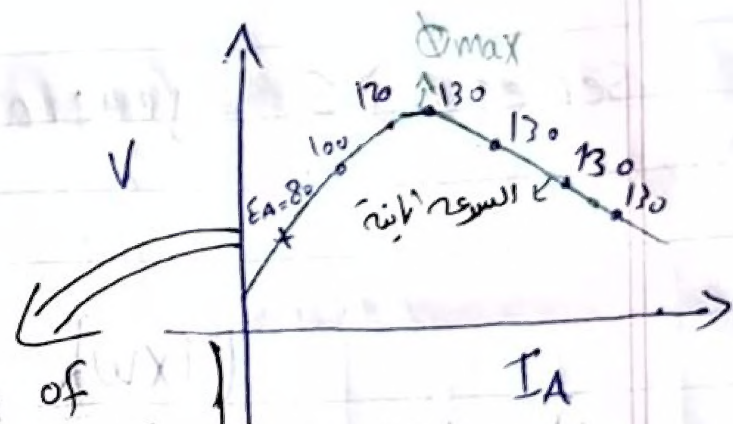
$$\begin{matrix} 460 \rightarrow 800 \text{ rpm} \\ E_A \rightarrow 1200 \end{matrix} \Rightarrow E_A = \frac{1200 \times 460}{800} = 690 \text{ V}$$

$$I_A = I_L = \frac{E_A}{R_A + R_{load}} = \frac{690}{0.12 + 10} = 68.18 \text{ A}$$

$$P_{output} = (I_L)^2 \times R_{load} = (68.18)^2 (10) = 46,485 \text{ Kwatt}$$

$$T_{ind} = \frac{E_A \times I_A}{\omega} = \frac{P_{out} + I_A^2 R_A}{\omega} = \frac{690 \times 68.18}{1200 \times \frac{2\pi}{60}} = 749 \text{ N.m}$$





(Characteristic curve of  
DC series generator)

Ex 8 DC-series generator  $\eta = 90\%$ ,  $P_{inP} = 10 \text{ hp}$   
 $V_T = 200 \text{ volt}$ ,  $n = 1000 \text{ rpm}$

Determine developed Power,  $T_{ind}$ ,  $T_{applied}$

$$P_{inP} = 746 \times 10 \text{ watt}$$

$$P_{out} = 0.9 \times 746 \times 10$$

$$V_T = 200$$

$$I_L = \frac{0.9 \times 746 \times 10}{200} = I_f = I_A$$

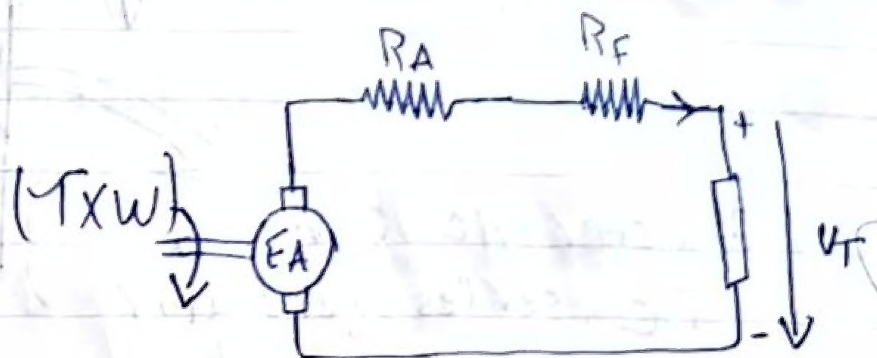
$$E_A = 200 + I_A(1.6) \Rightarrow$$

$$1) P_{dev} = E_A \times I_A$$

$$2) T_{ind} = \frac{E_A \times I_A}{\omega} = \frac{E_A \times I_A}{1000 \times \frac{2\pi}{60}} \quad \text{friction losses } P_{inP} - P_{dev}$$

$$3) T_{app} = \frac{10 \times 746}{1000 \times \frac{2\pi}{60}}$$

## 2) series DC generator



$$V_T = E_A - I_A R_A \quad I_A = I_L = I_f$$

$$I_L \uparrow = I_A \uparrow = I_f \uparrow \begin{cases} \Rightarrow \Phi \uparrow \Rightarrow E_A \uparrow \Rightarrow V_T \uparrow \\ \Rightarrow -I_A(R_A + R_f) \uparrow \Rightarrow V_T \downarrow \end{cases}$$

	$E_A$	$I_A$	$V_T$	
	110 V	10 A	100 V	$(R_A + R_s) = 1 \Omega$
50 turns	150 V	15 A	$150 - 15 \times 1 = 135 \text{ V}$	

10 turns	$E_A$	$I_A$	$V_T$
	100 V	10 A	90 V
	105 V	15 A	$105 - 15 \times 1 = 90 \text{ V}$
	108 V	20 A	$108 - 20 \times 1 = 88 \text{ V}$



\* Dc - shunt generator with  $\eta = 80\%$   
 $P_{inP}(\text{mech}) = 5 \text{ kW}$ ,  $V_T = 100 \text{ V}$ ,  $R_f + R_{adj} = 100 \Omega$

$R_A = 0,5 \Omega$ , speed = 1400 rpm

1) Determine developed power

$$P_{out} = 5000 \times 0,8 = 4000 \text{ Watt}$$

$$I_L = \frac{4000}{100} = 40 \text{ A}$$

$$I_f = \frac{V_T}{R_f + R_{adj}} = \frac{100}{100} = 1 \text{ A}$$

$$I_A = I_L + I_f = 40 + 1$$

$$P_{deve} = E_A \times I_A$$

$$E_A = 100 + 41 \times 0,5 = 120,5 \text{ V}$$

$$P_{deve} = 120,5 \times 41 = 4940,5$$

$$T_{ind} = \frac{P_{dev}}{\omega} = \frac{4940,5}{1400 \times \frac{2\pi}{60}} = 33,7 \text{ N.m}$$

$$T_{app} = \frac{5000}{1400 \times \frac{2\pi}{60}} = 34,1 \text{ N.m}$$



$$V_T \Rightarrow 220 - 505(,03 + ,004) \Rightarrow 202 \text{ Volt}$$

$$204 \rightarrow V_T \text{ at no load}$$

∴ Under Compound

$$* N_s = ?? \text{ flat}$$

$$I_f = 5 \text{ A}, n = 950 \text{ rpm}, I_L = 500 \text{ A}$$

$$V_T = E_A = 204, \quad I_f = I_f$$

$$204 = E_A - 505(,03 + ,004)$$

$$E_A = 221,1 \rightarrow 950 \text{ rpm} \Rightarrow I_f^* = 9,3$$

$$?? \rightarrow 1000 \text{ rpm} \Rightarrow I_f^* = 9,3$$

$$232,7 \text{ بر وجه على الجدول}$$

$$\text{flat} \rightarrow V_{n,L} = V_{f,L}$$

$$I_f^* = 9,3 \text{ A}$$

$$9,3 = 5 + \frac{505 \times W_s}{1200} \Rightarrow N_s = 10,2 \text{ turns}$$



$$Q_{net} \Rightarrow I_f^*$$

$$Q_{sh} \Rightarrow I_f$$

$$I_f^* = I_f \pm I_A \left( \frac{N_s}{N_f} \right) \quad \text{series field turns}$$

$$N_f \times I_f^* = N_f I_f \pm I_A \times N_s \quad \text{shunt field turns}$$

EX: DC generator, long shunt, Cumulative Compound,  $R_A = 0.03 \Omega$ ,  $R_s = 0.004 \Omega$ ,  $N_f = 1200$  turns,  $N_s = 5$

$I_f^*$	0	1	2.2	2.9	3.3	5.1	7.1	9.2
EA	11	33	100	140	167	215	222	232

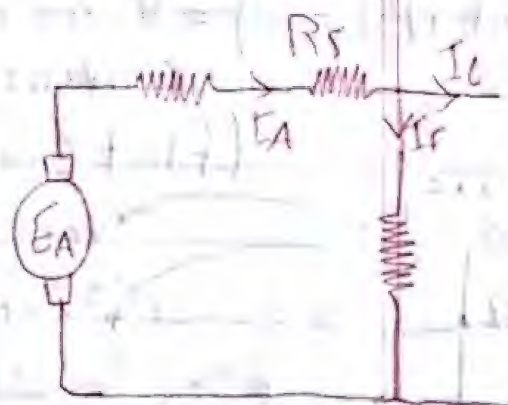
1) Determine terminal Voltage ( $V_T$ ),  $I_L = 500$  A

$$I_f = 5 \text{ A}, \quad n = 950 \text{ rpm}$$

$$I_f = 5 + 505 \times \frac{5}{1200} = 7.1 \text{ A}$$

$$222 \text{ V} \rightarrow 1000 \text{ rpm}$$

$$EA \rightarrow 950 \rightarrow EA = 211$$



$$V_T = EA - I_A(R_A + R_s) = 211 - 505(0.03 + 0.004) = 193.8 \text{ V}$$



80

# \* Compound Dc generator

(shunt + series) field circuit

$$E_A = K \Phi_{net} \omega$$

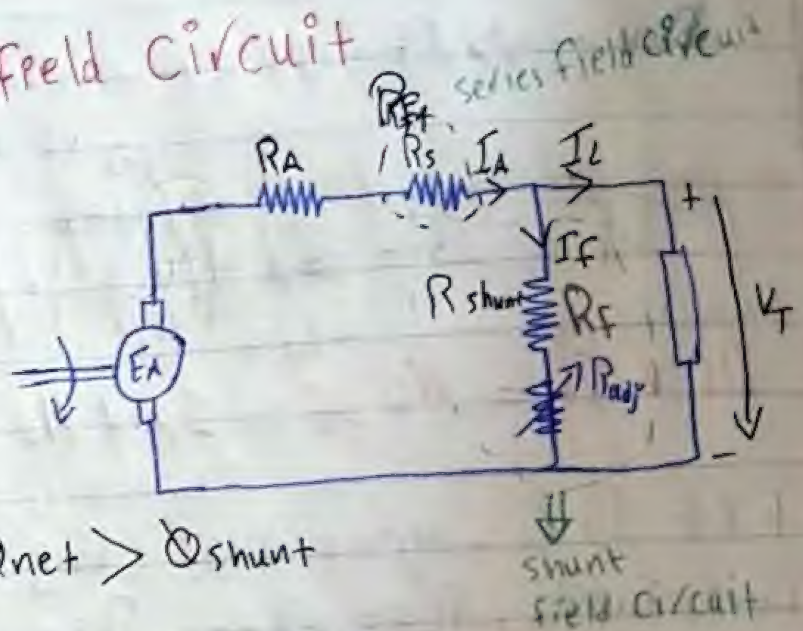
$$\Phi_{net} = \Phi_f + \Phi_s$$

(shunt)

(Cummulative)  $\Rightarrow \Phi_{net} > \Phi_{shunt}$

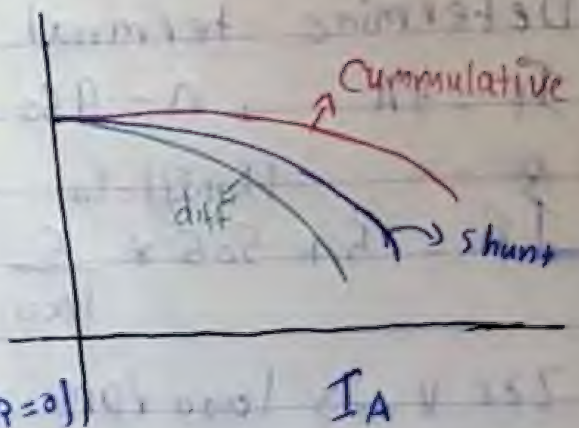
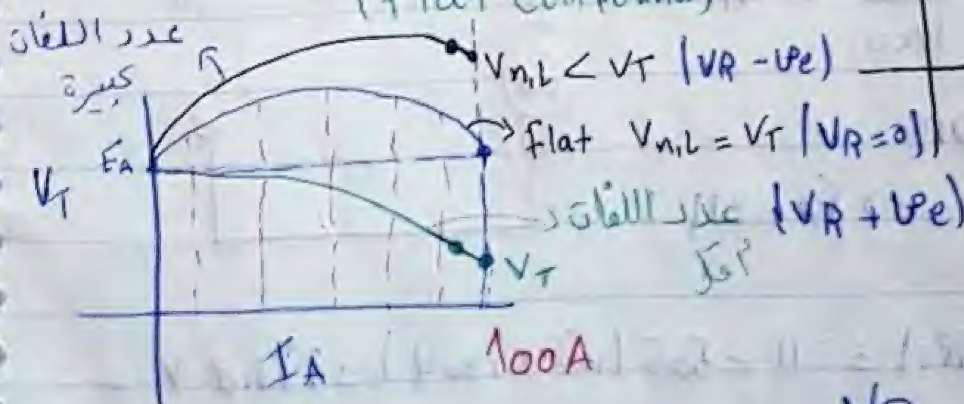
$$\Phi_{net} = \Phi_f - \Phi_s \Rightarrow \text{Differential}$$

$\Phi_{net} < \Phi_{shunt}$



$V_{no-load}(I_A = 0) = V_T$  at rated current

(flat Compound)



$$VR = \frac{E_A - V_T}{V_T} \times 100\%$$



$$I_f^* = 2,5 - \frac{100}{800} = 2,3 \text{ A}$$

$$\begin{array}{l} 87 \leftarrow 1800 \\ I_A \leftarrow 2000 \end{array} \Rightarrow E_A = 96,6 \text{ V}$$

$$V_T = 96,6 - 20 \times 0,25 \Rightarrow 91,6$$

$$V_T \text{ (no load)} \quad n = 2000 \text{ rpm}$$

$$I_f = \frac{100}{20+20} = 2,5$$

$$I_f^* = I_f - 0 = 2,5$$

$$91 \leftarrow 1800$$

$$E_A \leftarrow 2000 \Rightarrow E_A = 101,1 \text{ V} = V_T$$

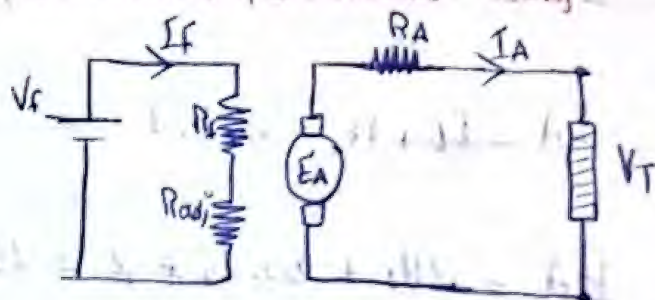
$$V_R = \frac{101,1 - 91,6}{91,6} \times 100\% = 10\%$$

- 3) If the generator has an armature reaction  $A_R = 100 \text{ A.turns}$   
 $I_{\text{load}} = 40 \text{ A}$ ,  $n = 2000 \text{ rpm}$ ,  $V_T = 100 \text{ V}$ , Determine  $R_{adp}$

$$E_A = 100 + 40 \times 0,25 = 110 \text{ V}$$

$$110 \rightarrow 2000 \text{ rpm}$$

$$E \rightarrow 1800 \Rightarrow E_A = 99 \text{ V}$$





\* EX: Sep excited DC generator with magnetization table as follow

$R_A = 2 \Omega$ ,  $R_f = 20 \Omega$ ,  $N_f = 800$  turns,  $V_f = 100$  V

$I_f^*$	1	2	2.3	2.5	2.7	2.9	3	4	1800 rpm
$E_A$	40	80	87	91	96	97	99	120	A
									V

1) Determine  $V_T$  at no load condition,  $n = 1700$  rpm

$R_{adj} = 20 \Omega$

$V_T = E_A$  at no load

من حالة ال no load  
ال  $I_f$  هي نفسها  $I_f^*$

$$I_f = \frac{100}{20 + 20} = 2.5 \text{ A}$$

9.1  $\rightarrow 1800$  rpm

??  $\rightarrow 1700$

$$E_A = 85.9$$

2) Determine voltage regulation if output current = 20 A

$A_R = 100$  A turns, Speed = 2000 rpm,  $R_{adj} = 20 \Omega$

\* Full load (20) A

$$I_f = \frac{100}{20 + 20} = 2.5 \text{ A}$$

AR at  
no load = 0



\* Armature reaction في generator

If Armature reaction is not compensated is not neglected

$$I_f^* = I_f - \frac{AR}{N_f}$$

sep excited

Shunt

Series

$$I_f = \frac{V_f}{R_f + R_{adj}}$$

$$I_f = \frac{V_T}{R_f + R_{adj}}$$

$$I_f = I_A = I_L$$

$$I_f^* = I_f - \frac{AR}{N_f}$$

$$I_f^* = I_f - \frac{AR}{N_f}$$

$$I_f^* = I_f - \frac{AR}{N_f}$$

Compound

$$I_f^* = I_f \pm I_A \frac{N_s}{N_f} - \frac{AR}{N_f}$$

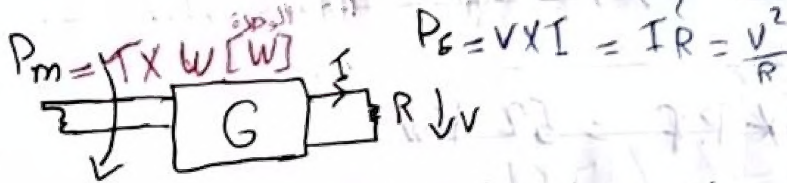


#Kojok

# Dc - Machine

- Dc generators

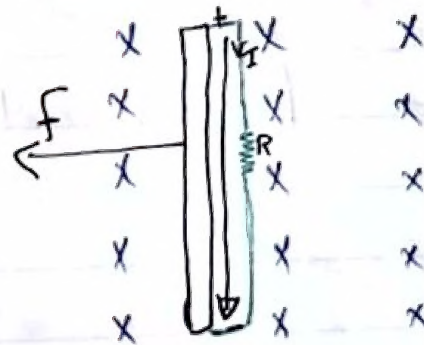
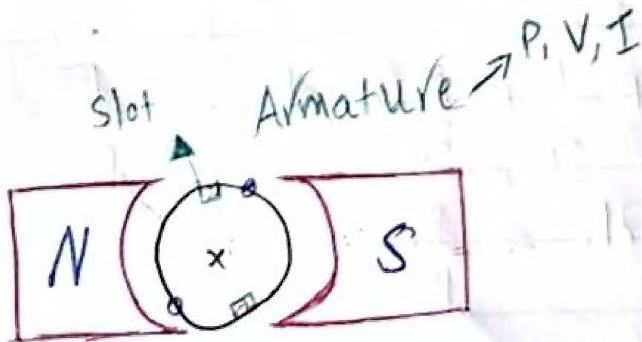
- Dc Motors



\* كيف يتم الحصول على الحركة

- 1) fuel
- 2) water (hydro)
- 3) Steam
- 4) wind (prime mover)

## Generator action



single layer

# of conductor  $Z = 2CN \Rightarrow$  # of turns  
# of coil



$$218 \rightarrow 1700$$

$$251,39 \rightarrow n \Rightarrow n = 1960,38 \text{ rpm}$$

\* With AR  $\Rightarrow 200$  ~~turns~~ A. turns

$$I_f^* = 1 - \frac{200}{1000} = 0,8 \text{ A}$$

$$215 \rightarrow 1700 \text{ rpm}$$

$$251,38 \rightarrow n \Rightarrow n = 1987,7 \text{ rpm}$$

b) Determine rotational losses, applied torque induced torque for Gas(a)

Without AR :

$$\text{Rotation losses} = P_{inP} - P_{out} - \text{elect losses}$$

$$= P_{inP} - P_{dev}$$

$$= 20 \times 746 - (251,39 \times 56,95) = 603,4 \text{ watt}$$

$$T_{app} = \frac{P_{inP}}{\omega} = \frac{20 \times 746}{1960,38 \times \frac{2\pi}{60}} = 72,7 \text{ N.m}$$

$$T_{ind} = \frac{E_A \times I_A}{\omega} = \frac{251,39 \times 56,95}{1960,38 \times \frac{2\pi}{60}} = 69,7 \text{ N.m}$$



$$218 \rightarrow 1700$$

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$$T_{ind} = \frac{E_A \times I_A}{\omega} = \frac{251,39 \times 56,95}{1960,38 \times \frac{2\pi}{60}} = 69,7 \text{ N.m}$$



Ex: DC sep excited generator

$$R_A = 0.5 \, \Omega, R_f = 20 \, \Omega, V_f = 200 \, V$$

Magnetization table measured at constant speed = 1500 rpm

$I_f (A)$	0.5	1	1.5	2	2.2	2.5	3
$E_A (V)$	180	185	190	200	205	210	212

1) Determine  $V_t$  at no load,  $R_{adj} = 180 \, \Omega$ ,  $n = 2000 \, \text{rpm}$

$$I_f = \frac{200}{20 + 180} = 1 \, A$$

$$185 \, V \rightarrow 1500 \, \text{rpm}$$

$$E_A \rightarrow 2000 \, \text{rpm}$$

$$\Rightarrow E_A = \frac{2000 \times 185}{1500} = 246.6 \, V$$

2) Determine Required for the generator to deliver output 10 kW,  $V_t = 200 \, V$ ,  $R_{adj} = 80 \, \Omega$

$$I_f = \frac{200}{20 + 80} = 2 \, A$$

$$I_L = \frac{10 \times 10^3}{200} = 50 \, A \Rightarrow I_A = I_L$$

$$E_A = V_t + I_A R_A = 200 + 50 \times 0.5 = 225 \, V$$

$$200 \rightarrow 1500$$

$$225 \rightarrow n$$

$$\Rightarrow n = \frac{225 \times 1500}{200} = 1687.5 \, \text{rpm}$$